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Study of 2-Amino-2-Methyl-1-Propanol Effect on Corrosion of Boiler Low Carbon Steel Pipes in Presence of Sodium Sulfite

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ABSTRACT

This paper studies the effect of 2-Amino-2-mthyl-1-propanol ($C_3H_{11}NO$) on corrosion behavior of boiler steel pipes with low carbon content at sodium sulfite (Na_2SO_3) in the additive mixtures form as oxygen scavengers in the boiler feed water.
Experiments were done at temperatures (100 - 150) ºC and pressures (5 - 9) × 101.3 KN/m² in cylinder autoclave with 7.4 ppm dissolved oxygen in used water, then the corrosion rate is measured by weight loss technique and the concentration of dissolved oxygen in feed water was determined before and after the experiment by Winkler method (Titration).
This analysis can provide valuable information for mixture scavengers and corrosion behavior on boiler steel pipes with range of used temperature and pressure. The better ratios found is 60 ppm for every one of amine and sulfite, with the best result in decreasing corrosion rate in acceptable way. The above mentioned ratio is optimal and recommended. This opens up the field for formulation synergetic packages of additives as O_2 scavengers .
Keywords: Oxygen Scavenger, Na_2SO_3, $C_3H_{11}NO$, Boiler Steel Pipes, NA-Sulfite & 2-Amino-2-mthyl-1-propanor Additive Package

INTRODUCTION

The main use of water in industry is transferring of heat and the production of steam[1]. The steam boilers are constructed according to various designs, but they consist essentially of low carbon steel for water which is heating by hot gases[2,3].
Appreciable corrosion of steel requires dissolved oxygen in neutral solution[1]. Therefore, the dissolved oxygen was the main cause of corrosion in neutral aqueous solution, because it is represented the main cathodic reaction which occurs in that cathodic areas[4].

$$2H_2O + O_2 + 4e^- \rightarrow 4OH^- \quad \text{Cathodic (reduction) reaction}$$

While the anodic reaction represent the oxidation of metal iron to its ions and transfer into the solution, which causes losing in the weight of metal[5,6].

$$Fe \rightarrow Fe^{+2} + 2e^{-} \qquad \text{Anodic (oxidation) reaction}$$

The oxygen is very energetic cathodic and depolarizer. With an increase of oxygen concentration in the water can expect an increase in the rate of corrosion of metals, particularly steel[6,7]. Therefore, any remained of dissolved oxygen in the water of boiler unites quantitatively with the metals of the boiler system and causing pitting of the boiler tubs and general attack elsewhere[3,8,9,10]. Stringent control of dissolved oxygen to absolute minimum levels is an obvious requirement to control corrosion in closed high temperature boiler system[1].

Dissolved oxygen may be removed mechanically or chemically. Mechanical deaeration involves either heating or purging with a counter flow of gas to strip the oxygen from the water. Both heating and stripping may be accomplished with a counter flow of steam[1,11]. Chemical scavenging is usually necessary to reduce dissolved oxygen to levels acceptable for applications[1,12,13].

Sodium sulfite has been used as oxygen scavenger[12], which is very effectively in feedwater and neutral solution where oxygen reduction is the controlling corrosion cathodic reaction[6]. And amine components are well known in the boiler feed water. The selection one or more of amines must be based upon system pressure, temperature, Complexity types of equipments used and their ability to retard corrosion rate[13,14,15]. Typical of such amines are 2-amino-2-methyl-1-propanol[13,14,15,16]. In addition to that, mixtures of synergetic packages of amines and with other additives can be used [14,16,17,18,19].

Research Aim

The aim of this research is the control on corrosion behavior and the minimizing in corrosion rate of carbon steel through using optimum package of sodium sulfite and 2-amino-2-methyl-1-propanol in feed water of boiler system at different operation conditions (DOC).

EXPERIMENTAL

Experiments were done at temperatures (100 - 150) ºC and pressures (5 - 9) × 101.3 KN/m² in cylinder autoclave apparatus with a wall thickness of 12 mm, heating tape surrounded the outside of the autoclave, temperature controller and recorder, pressure gauge, N_2 gas cylinder, sensor record temperature and control valve to get rid of excess saturated steam. Maximum capacity of the autoclave is 1700 ml, as shown in figure 1.

The corrosion behavior of carbon steel in the investigation was carried out using weight loss technique under controlled condition of temperature, pressure & high efficiency amounts (20 - 60 ppm) for every one of amine[13] and sodium sulfite[12] as additive package of oxygen scavengers. Three rectangular specimens were used for measuring the corrosion rate of low carbon steel in gram per square meter per day (g/m²/d). The concentration of dissolved oxygen in feed-water was determined before and after the experiment by Winkler method (Titration) at atmospheric condition.

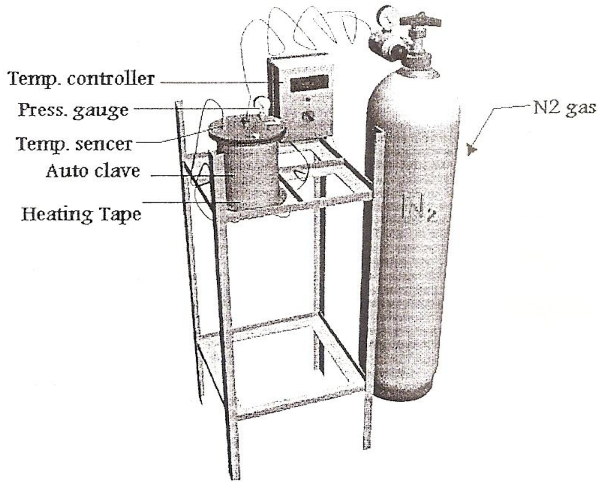

Figure 1. Process Measurement Unit

The chemical composition analysis of low carbon steel alloy specimen was made at the State Company of Geological Inspection- Iraq. It is shown in the Table 1.

Table 1. Chemical analysis of carbon steel alloy specimens

Element	Percentage Content Wt%
C	0.085-0.1
Mn	0.4-0.6
S	0.05
P	0.04
Ni	0.017
Cr	0.014
Mo	0.061
Fe	Remainder

RESULTS AND DISCUSSION

Results of measurement of dissolved oxygen in feedwater by titration before and after experiment are given in table 2.

Figure 2 explains that the concentrations of dissolved oxygen before experiment is 7.4 ppm and after adding (0 , 20 , 40 , 60) ppm of amine on constant concentration of Na-Sulfite (20 ppm) are (3.5 , 3.21 , 2.05 , 1.7) ppm respectively. But when the concentration of Na-sulfite is fixed 60ppm and the concentrations of amine are (0 , 20 , 40 , 60) the remaining concentrations of dissolved oxygen are about nil (0.05)ppm. This means that the increasing in concentration of 2-amino-2-methyl-1-propanol (20 , 40 , 60 ppm) on fixed amount of Na-sulfite (60 ppm) leaded to highest efficiency of scavenging oxygen, thus decreases the corrosion rate of boiler steel pipes.

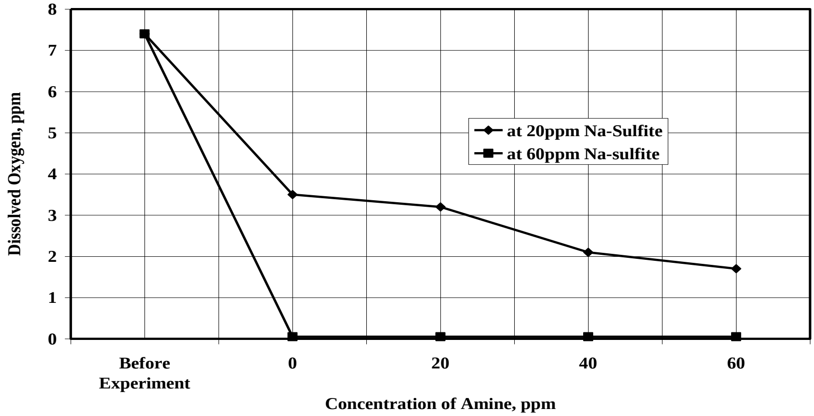

Figure (2): Effevt of conceentration of amine and sodium sulfite on concuming of oxygen in feed water

Results of effect of additions of the 2-amino-2-methyl-1-propanol on corrosion rate at 20 ppm of Na-sulfite and at different temperatures and constant pressure 5x101.3 KN/m² are given in figure 3.

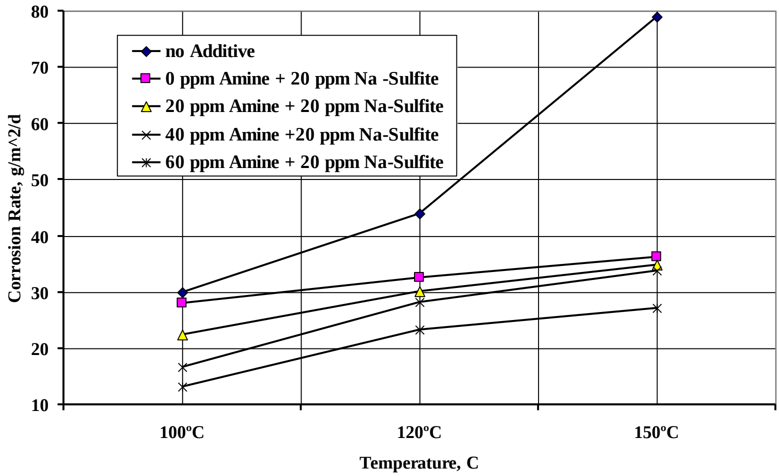

Figure (3): Effevt of additions of the (Amine and sodium sulfite) on corrosion rate steel pipes at 5*101.3 KN/m^2 and different tempertures.

From figure 3. It is noted that at constant pressure (5x101.3 KN/m²) the corrosion rate increases up to high level (30 - 80 g/m²/d) by increasing the operation temperature (100 – 150) ºC in the closed system. This increasing is due to the dissolved oxygen, which accelerates corrosion. The oxygen is a strong and rapid oxidizing agent in cathodic reactions and this case is confirmed by references[3, 4]. When corrosion is controlled by diffusion of oxygen, the corrosion rate at given oxygen concentration (7.4ppm) approximately doubles from 43 to 80 g/m²/d for 30ºC rise in temperature from 120 to 150 ºC at constant pressure (5x101.3 KN/m²) . However, in a closed system, oxygen can not escape and the corrosion rate continues to increase with temperature. And it is noted that the presence of inhibitor (Amine + Na-Sulfite) leaded to decreasing the corrosion rate up to lower levels (13 g/m²/d). In addition, it is noted that when the temperature increases the corrosion rate increase for all additions of (2-amino-2-methyl-1-propanol + Na-Sulfite), but when adding the additive package (2-amino-2-methyl-1-propanol + Na-Sulfite) the starting point of corrosion rate was shifting down from 30 to 13 g/m²/d. This case is due to the dissolved oxygen in feed water solution was approximately consumed with the increase of concentration of oxygen scavenger (2-amino-2-methyl-1-propanol + Na-Sulfite). The figure explanes that the increasing in concentration of 2-amino-2-methyl-1-propanol (20 , 40 , 60 ppm) on fixed amount of Na-sulfite (20 ppm) leaded to high efficiency of scavenging oxygen and decrease the corrosion rate of boiler steel pipes specially at ratio (60:20) ppm of amine and sodium sulfite in feedwater solution.

Results of effect of additions of the 2-amino-2-methyl-1-propanol on corrosion rate at 60 ppm of Na-sulfite and at different temperatures and constant pressure 5x101.3 KN/m² are given in figure 4.

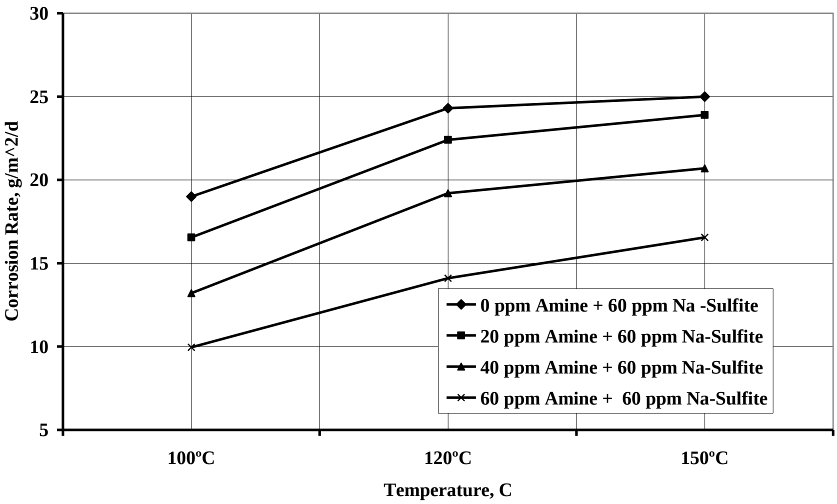

Figure (4): Effevt of additions of the (Amine and sodium sulfite) on corrosion rate of boiler steel pipes at 5*101.3 KN/m^2 and different tempertures.

Figure 4 explains that the additions of 2-amino-2-methyl-1-propanol (20, 40, 60) ppm to the effective amount of Na-Sulfite (60ppm) against corrosion rate of boiler steel pipes. This is according to reference Harharah and his group[12]. We noted that the efficiency again increases by the addition of 2-amino-2-methyl-1-propanol + Na- Sulfite from 19 to 10 g/m²/d. The best ratio found is 60 ppm for every one of amine and Na-sulfite, with the best result in decreasing corrosion rate in acceptable way. Therefore, we well recommend this synergetic ratio of additive package (60ppm amine + 60ppm Na-sulfite) as oxygen scavenger and decreases corrosion reaction in low carbon steel pipes of boilers . This is conformed by references Saad and Harharah[13] and Harharah et all[12] for individual compound, too.

Results of ratio (60ppm amine + 60ppm Na-sulfite) at different temperatures and pressures are given in figure 5.

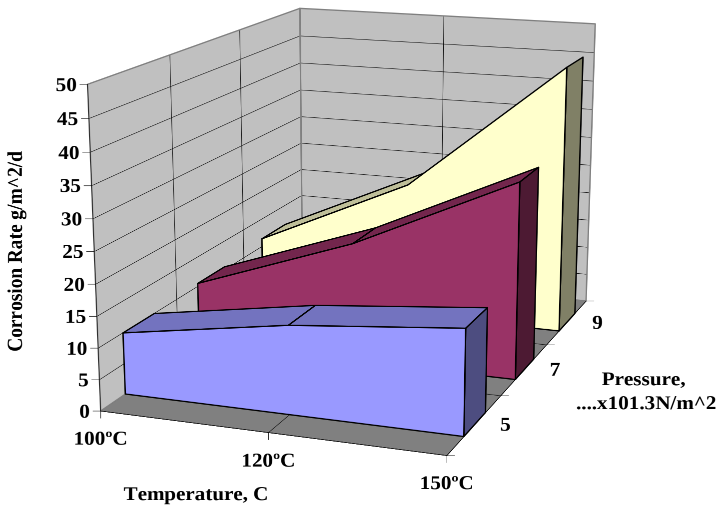

Figure (5): Effevt of additions of the (60 ppm Amine + 60 ppm sodium sulfite) on corrosion rate boiler steel pipes at different operation conditions..

The figure 5 explains that influence of pressure changes (5 , 7 , 9) x101.3KN/m² on the corrosion rate at 100ºC is lower than the influence of the same values of pressure on corrosion rate at 150ºC. Therefore, at 100ºC and the values of pressure are (5 , 7 , 9) x101.3KN/m² the corrosion rates are (10 , 10.5 , 11.4) g/m²/d respectively. And at 150ºC and the values of pressure are (5 , 7 , 9) x101.3KN/m² the rates of corrosion are (16.55 , 32.12 , 45.5) g/m²/d respectively. Then that the increasing in the corrosion rate not depends only on the temperature, but also depends on the pressure. That increasing in corrosion rate with increasing in pressure may be for the reason of increasing the velocity of feed solution, which leads to increasing of the diffusion of the oxygen. With other words the increasing in temperature and pressure leaded to increasing in corrosion rate.

CONCLUSIONS

This analysis can provide valuable information for mixture scavengers and corrosion behavior on boiler steel pipes with range of used temperature and pressure. The increasing in temperature and pressure leaded to increasing in corrosion rate, but when adding the additive package (2-amino-2-methyl-1-propanol + Na-Sulfite) the starting point of corrosion rate was shifting down. The better ratio found is 60 ppm for every one of amine and sulfite in mixture, with the best result in decreasing corrosion rate in acceptable way. The above mentioned ratio is optimal and recommended. This opens up the field for formulation synergetic packages of additives as oxygen scavenger .

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دراسة تأثير 2-أمينو-2-ميثيل-1-بروبانول على تأكل أنابيب الغلاية الفولاذية منخفضة الكربون في وجود الصوديوم سولفايت

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ملخص

يدرس البحث تأثير مركب 2-أمينو-2-ميثيل-1-بروبانول $C_3H_{11}NO$ على سلوك التآكل لأنابيب الغلاية الفولاذية ذات المحتوى الكربوني المنخفض في وجود مركب الصوديوم سولفايت Na_2SO_3 في صيغة مخاليط الإضافة الكيميائية ككاسح للأكسجين المذاب وسط لقيم ماء الغلاية.

نفذت التجارب عند درجات حرارة (100 – 150) م° وضغوط (5 – 9) ×101.3كيلو نيوتن\م² وسط أوتوكلاف اسطواني المعبأ بالماء الخالي من المعادن الحاوي على 7.4 جزء من المليون من الأكسجين الذائب، عندها يقاس معدل التآكل بواسطة تقنية فقد الوزن.كما يعين تركيز الأكسجين الذائب بواسطة طريقة وينكلر (طريقة المعايرة) قبل وبعد التجربة.

هذه الدراسة استطاعة أن تزودنا بمعلومات عن مخاليط الكاسح للأكسجين وكذلك سلوك التآكل على أنابيب الغلاية الفولاذية وسط المدى من درجات الحرارة والضغوط المستخدمة. ووجدنا أن أفضل العلاقة الكمية هي 60 جزء من المليون لكل واحد من الأمين والسولفايت، حيث بواسطة هذا السياق وجدنا النتيجة المثلى في خفض معدل التآكل . وبهذا فإن النسبة المذكورة أعلاه هي الموصى بها. مما يفتح المجال لصياغة حزم جديدة من الإضافات الكيميائية ككواسح للأكسجين الذائب.